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Management of Sarcopenic Obesity for Older Adults with Lower-Extremity Osteoarthritis

Tsan-Hon Liou, Chun-De Liao and Shih-Wei Huang

Abstract

Lower-extremity osteoarthritis (OA) is a prevalent musculoskeletal disease in elder population. The main symptom of OA is pain which leads to muscle weakness and physical disability. Recently, muscle weakness, function limitation, and severity of disease in OA are addressed to aging-related muscle attenuations. Therefore, elder individuals with OA are under potential sarcopenia risks. In addition, obesity, which exerts negative impacts on disease outcomes, has become a burden in OA population. Under multifactor risks of OA, it is important to identify effectiveness of multidisciplinary management for such elder population to prevent sarcopenic obesity and maintain physical function. Previous studies have indicated that diet intervention (DI) using protein supplement, dietary protein, or weight loss enhances exercise efficacy in terms of additional muscle mass and strength gains to exercise training (ET) for elder individuals with high sarcopenia and frailty risks. However, it remains unclear whether DI in combination with ET augments any benefit for older adults with lower-extremity OA. This chapter aimed to review the effects of DI plus ET on muscle mass, strength, and physical function outcomes in older individuals with lower-extremity OA.

Keywords: sarcopenia, osteoarthritis, protein supplement, exercise training, muscle mass, function outcome

1. Introduction

Elderly population aged 65 and over is a substantially growing population which is estimated to exceed 16% of global population worldwide in the year of 2050 [1]. Elongation of life expectancy is accompanied with an increase of chronic diseases leading to restricted physical function and disabilities in daily life [2, 3], among which musculoskeletal disorder is a significant public health issue with 7.5–35.2% of the elder people having mild to moderate musculoskeletal conditions [3, 4] and has become the second cause of global burden worldwide compared with other causes of morbidity-mortality [5].

Among the age-related musculoskeletal disorders, osteoarthritis (OA) is one of the most prevalent musculoskeletal diseases from the sixth to the ninth decade of lifespan, especially the OA in lower extremities is closely associated with limitations of functional activities and participation [6]. In addition, sarcopenia, obesity, or in combination of both called sarcopenic obesity have great impacts on physical function in older adults [7, 8]. The impacts of sarcopenia on musculoskeletal system

are accounted to the risks of physical limitation in elder individuals, especially those with hip or knee OA [9, 10]. The age-related muscle dysfunction can be addressed to impairments in musculoskeletal system as well as neuromuscular system [11, 12]. With respect to the underlying mechanisms of sarcopenia in older population, muscle atrophy (i.e., decline in muscle size) plays a key role in muscle attenuation [11], especially the type II myofiber [13]. The loss of muscle mass occurs progressively from middle-age by a rate of 0.47% per year in men and 0.37% per year in women [14]; in people aged 75 years, muscle mass is decreased at a rapid rate of 0.64–0.70% per year in women and 0.80–0.98% per year in men and in severe diseases can lead to a loss of approximate 50% by the 8–9th decade of life [15]. Loss of skeletal muscle mass is commonly accompanied with deficits in muscle function such as muscle weakness, which is relevant to clinical presentation of sarcopenia as well as OA. Reid et al. indicated that leg lean mass is strongly associated with muscle strength ($r = 0.78, p < 0.01$) [16]. Liu et al. further indicated that low handgrip strength is strongly associated with decreased skeletal muscle mass in elder individuals [17]. Because of that loss of muscle strength may lead to physical difficulty and disability, low muscle mass has been identified as a crucial factor of functional limitation of physical mobility such as walk capability and chair rise [8, 17, 18].

Recently, the disease progression of knee and hip OA has been attributed to age-related decline in muscle mass (i.e., sarcopenia). Toda et al. reported that older women with knee OA experienced significantly lower leg lean mass relative to body weight (%) by a mean \pm standard deviation of $19.2 \pm 2.7\%$, compared with the healthy control ($21.0 \pm 2.9\%$; $P < 0.0001$) [19]; Lee et al. observed similar results which indicated that older adults with knee OA had a mean appendicular skeletal muscle mass of 15.6 kg which is significant lower than that of healthy control (17.3 kg, $P < 0.001$) [20]. Additionally, Jeon et al. reported that lower skeletal muscle mass independently associated with knee radiographic OA [odds ratio (OR) 1.34; 95% confidence interval (CI) 1.04, 1.75] [21]. Therefore, older people with knee OA are considered at high risk of sarcopenia [22]. Grimaldi et al. observed muscle mass decreased in patients with hip OA in terms of 2.6–14.4% muscle atrophy of gluteal muscle group in the affected side compared to those in the uninvolved side, whereas such asymmetry in muscle volume ranged from 0.4 to 3.7% in control peers [23]; in addition, the muscle volume asymmetry is positively associated with disease progression of hip OA, indicating that patients with moderate to severe OA may experience greater muscle mass loss than mild-severity or asymptomatic patients [24]. Therefore, the OA population faces not only age-related muscle attenuation (i.e., sarcopenia) but also the disease-induced muscle loss.

The sarcopenia, obesity, and OA are becoming major threats to aging society and have been recognized as important health issues [8, 25–27]. The relationships among sarcopenia, obesity (i.e., sarcopenic obesity), and OA have been discussed. Kemmler et al. conducted an observational study to investigate the prevalence of sarcopenia in community-dwelled women who aged 70 years and older; the results indicated that elder women with lower-extremity OA exhibited a significantly higher rate of sarcopenia (9.1%) than nonarthritic peers (3.5%) [28]. Jin et al. reported that elder men and women with sarcopenic obesity showed significantly higher risks of exhibiting knee OA (OR = 1.92–2.43) compared with the healthy control groups [29]. Misra et al. conducted a longitudinal study of the risk of radiographic OA in relation to sarcopenic obesity; the result showed that elder people with sarcopenic obesity (RR = 1.91) had increased risks of exhibiting knee OA within a 5-year interval of follow up [30]. Therefore, preventive efforts for the obese elder individuals may need to focus not only on reducing sarcopenia but also on improving sarcopenic obesity to reduce the growing incidence and prevalence of knee OA.

2. Treatments and management for sarcopenia in elderly

Sarcopenic obesity originates from a multifactorial consequence of aging and its related physical inactivity [31], which especially exerts negative impacts to obese elderly populations [32]. Several approaches for management of sarcopenic obesity have been recommended including pharmacological interventions, exercise interventions, and nutrition interventions to counteract muscle loss and physical declines in obese older adults [33]. According to the recommendations from the European Society for Clinical Nutrition and Metabolism Expert Group [34], there are urgent needs for elder people with a risk of sarcopenic obesity to incorporate nutrition intervention and muscle strengthening exercise to prevent the functional decline.

2.1 Protein supplement plus exercise training for sarcopenic obesity

Obesity has become epidemic burden in elderly population [25]. Sarcopenic obesity, a recently identified phenotype of obese elderly population, is developed based on an underlying additive effect of sarcopenia and obesity and is referred by the coexistence of diminished muscle mass and increased fat mass. Sarcopenia has been characterized by age-related muscle degeneration [35], and obesity with an increased body fat exerts negative impacts on the skeletal muscle turnover and its homeostasis [31]. Such deteriorations of muscle mass loss originated from aging process result in muscle dysfunction which may further lead to physical deficits in frail elderly [36]. Furthermore, older adults who are identified as overweight or obesity have been observed suffering high risks of physical disability [37, 38]. Accordingly, sarcopenic obesity had been identified to be associated with more physical limit than either pure sarcopenia or obesity and was served as a risk to disability and frail life style [8, 39]. Therefore, the preservation of muscle mass and strength are vital for obese older adults to yield physical activities in daily life.

Aging-related attenuation of skeletal muscle mass had been addressed to a smaller muscle fiber size rather than loss of fiber number and characterized of type II myofiber phenotype dominant [13, 40]. In addition, sarcopenic muscles remain in a state of failing compensatory effort in an attempt to stave off muscular degeneration and atrophy [41]. Given the facts that myofiber hypertrophy activated by satellite cells is largely dependent on both net muscle protein synthesis and satellite cell recruitment through serious cellular processing mechanism [42, 43], and that both age-associated sarcopenia and obesity are associated with an over expression of myostatin which functions as a protein inhibitor negatively regulating the skeletal muscle growth and homeostasis with inhibiting the myoblasts proliferation and differentiation [44–46], it is important to identify whether resistance exercises exert any effect on the myofiber type-specific muscle mass loss in obese aged people. In such scenarios, previous trials claimed that age-related Type II myofiber phenotype atrophy would be improved following resistance exercise training by means of satellite cell proliferation and an increase in the rate of muscle contractile and mitochondrial protein synthesis, which further contributed to myofiber hypertrophy [40, 42, 47–51].

Progressive resistance exercise training (RET) has been used as an effective way of improving muscle function and increasing muscle mass by stimulating muscle protein synthesis in elder people [31, 49, 52, 53]. Liao et al. further indicate that elastic RET exerts benefits on lean mass and physical mobility in older women with sarcopenic obesity [54]. With respect to multidisciplinary interventions for prevention of sarcopenia in elder populations, an additional protein supplements (PS) has also been believed to augment the effects of resistance training on muscle mass

gain in older adults [55, 56]. For obese elderly individuals with energy restricted diet, PS has its effect on reduction of losing muscle mass during caloric restriction-induced weight loss [57]. However, the effects of PS plus RET on muscle mass and strength gains for obese elder people remain controversy. While several studies identified the effects of PS on muscle mass accretion and strength gain during resistance training in sarcopenic or obese elderly individuals [58], some concluded that PS provides no additional benefit in resistance-trained obese elder individuals [59, 60]. Furthermore, few systemic review studies have summarized these results in obese elder individuals. Whether PS during RET exerts any benefit on augmentation of muscular and functional performance in obese elder people remains unclear.

Liao et al. conducted a systemic review and meta-analysis study to investigate effects of PS plus RET for obese elder people [61]. Main results of Liao's study showed an overall effect on lean body mass (LBM) and fat mass with significant standardized mean differences (SMDs) of 0.58 (95% CI = 0.32, 0.84, $P < 0.0001$) and -0.61 (95% CI = -0.93 , -0.29 ; $P = 0.0002$) favoring PS plus RET, respectively; similar results were observed in leg strength (SMD = 0.69, 95% CI = 0.39, 0.98; $P < 0.00001$) and short physical performance battery test (SMD = 0.44, 95% CI = 0.11, 0.78, $P = 0.009$). The results indicate that PS during RET intervention may potentially positively contribute to changes in the body composition of overweight and obese older people. However, based on the lower body mass index (BMI) subgroup (mean BMI $< 30 \text{ kg/m}^2$) exhibited greater changes in muscle volume and handgrip strength whereas the subgroup with mean BMI $\geq 30 \text{ kg/m}^2$ did not after PS, obese older individuals may be resistant to PS to some degree [61].

2.2 Associations of muscle mass changes with intervention effects on muscle strength and physical capability after protein supplement plus exercise training

Multidisciplinary approaches are recommended for elderly individuals who have high sarcopenia or frailty risks, including nutrient intervention alone, exercise training alone, or combination of both [62–66], and among which protein supplement combined with exercise training (PS + ET) has been widely employed to augment lean mass gain, strength gain, and physical function enhancement in elderly individuals, irrespective of PS types and exercise protocols [65, 67–69]. However, whether intervention-induced changes in muscle mass contribute to strength gain and physical mobility improvement after PS + ET remains unclear. Several previous meta-analysis studies have reported that an increase in lean mass is accompanied by significant increases in strength gain [61, 68, 70–72] as well as physical mobility [68, 72] following PS + ET; however, such simultaneous increases in lean mass with strength [67, 73] (or physical function [61, 71]) were not observed by other researchers. Low muscle mass strongly predicts strength loss and mobility limitations in older adults [17, 74]; in addition, sarcopenia has been addressed to suppressed muscle protein turnover and homeostasis [75, 76]; therefore, identification of relationship between the muscle mass changes and physical improvements in response to PS + ET can facilitate clinical practitioners to efficiently make optimal decisions and set appropriate intervention strategies for elderly patients who are diagnosed as sarcopenia or frailty.

Liao et al. conducted a systemic review and meta-regression study to determine the associations of lean mass changes with treatment effects on strength and physical mobility after PS + ET [77]. Main results of Liao's study showed an overall effect on LBM and appendicular lean mass (ALM) with significant SMDs of 0.66 (95%CI: 0.41–0.91, $P < 0.00001$) and 0.40 (95%CI: 0.15–0.66, $P = 0.002$) favoring PS + ET, respectively; similar results were observed in leg strength (SMD = 0.65, 95% CI:

0.39–0.90; $P < 0.00001$) and walking capability (SMD = 0.33, 95% CI: 0.14–0.52; $P = 0.0006$). Meta-regression analysis results of Liao’s study showed that significant associations were observed between changes in ALM ($\beta = 0.08$, $P = 0.003$) and SMDs of leg strength; the results further indicated that elderly individuals who achieved an increase in ALM of $>2.5\%$ in response to PS + ET may have obtained a positive effect size of leg strength. In addition, changes in ALM were significantly associated with effect sizes of walking capability ($\beta = 0.17$, $P = 0.04$). According to the Liao’s results, intervention-induced muscle mass gains have contributions in strength gain and function recovery after PS + ET, particularly the elderly who have sarcopenia and frailty risks.

3. Management of muscle deficits for mild to moderate severity of osteoarthritis

Since OA has been recognized as a serious musculoskeletal disease [78], managements of OA comprise multidisciplinary interventions including pain medications and nonpharmacological treatments for those patients who exhibit mild to moderate symptoms. However, surgical treatments such as total joint arthroplasty that could help to relief pain and improve joint function (e.g., range of motion and strength) [79] are commonly recommended at the end stage of OA.

Evidences regarding the effects of ET alone or PS plus ET on muscle mass, strength, and physical mobility have been well established in elderly populations with sarcopenia (**Figure 1**). However, whether ET alone or PS plus ET exert any benefit on muscle mass and function outcomes remains unclear. Based on that low muscle mass is closely associated with OA and elder individuals with OA have high sarcopenia risk [10, 28], it is urgent to generate effective strategy to manage this condition for the rapidly growing OA population. In addition, it is necessary

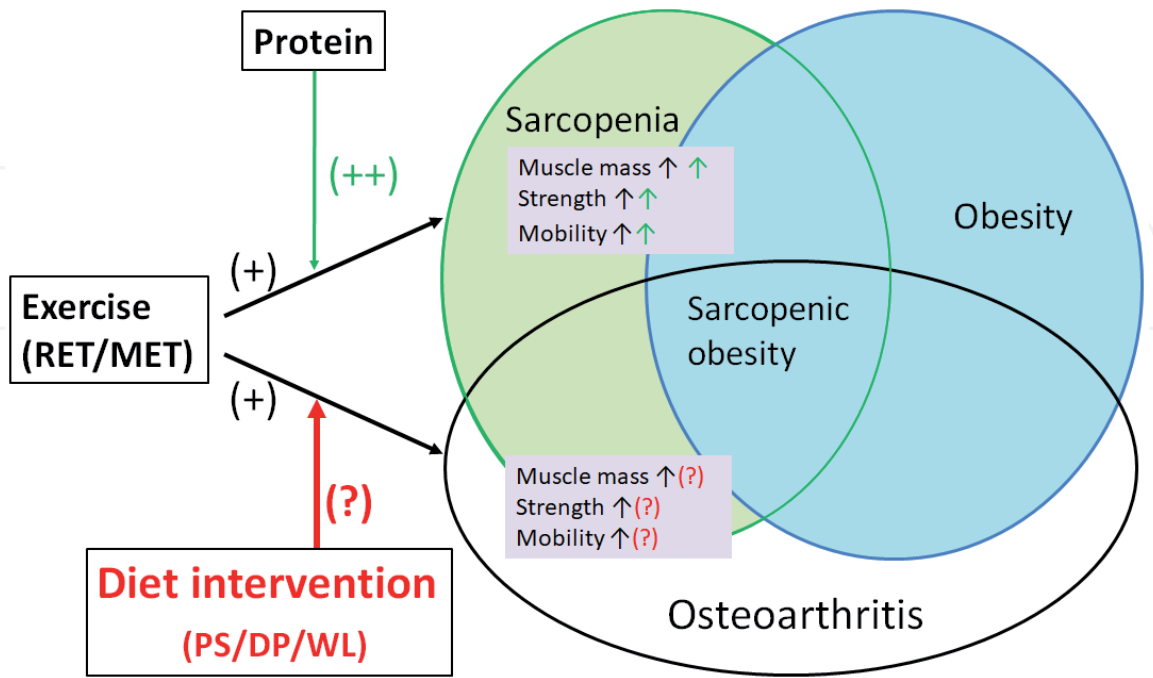


Figure 1. Summary of evidences regarding effects of exercise and diet interventions on sarcopenia, sarcopenic obesity, and osteoarthritis. Black, green, and red arrow lines indicate exercise alone, protein supplement plus exercise, and diet interventions plus exercise, respectively. (+): significant intervention effect; (++): significantly additional effect; (?) unclear additional effect. RET, resistance exercise training; MET, multicomponent exercise training; PS, protein supplement; DP, dietary protein; WL, weight loss.

to identify evidence of intervention effects on muscle mass and strength gains for elder people with OA.

3.1 Exercise training

Among the interventions of OA, exercise therapy is recommended as one of the first-line treatments [80]. Exercise exerts benefits on pain reduction, muscle strength, and physical function in elder individuals with OA, regardless of exercise types [81]. Especially, the muscle strength-based exercise training (MSE) has been encouraged to minimize degenerative muscular function associated with aging [82, 83], because of that elder individuals experience well muscular adaptations in terms of muscle morphological and architectural changes responding to MSE [84]. Therefore, MSE has been recommended for elder people with OA to augment muscle volume and enhance muscle hypertrophy [80].

Previous results have shown that MSE exerts benefits on muscle mass gain in elderly people. Churchward-Venne et al. indicated that older individuals achieved significantly temporal changes in whole body lean mass at 12-week and 24-week follow up by 0.9 ± 0.1 kg ($P < 0.001$) and 1.1 ± 0.2 kg ($P < 0.001$), respectively, responding to prolonged resistance-type MSE with an intensity of 60–80% 1RM and an intervention duration of 24 weeks [85]. In a meta-analysis, Peterson et al. indicated that resistance exercise exerts significant effects on increasing LBM with a pooled mean difference of 1.1 kg (95% CI: 0.9–1.2 kg) compared to the controls in older people [53].

The MSE has been served as the most promising intervention for sarcopenic elderly [62, 86] as well as those with OA [87–90] to increase strength and improve mobility. Due to that MSE enables older adults to yield increased muscle anabolic resistance occurring with advancing age [91, 92], resistance-type exercise training (RET) as well as multicomponent exercise training (MET) have been considered beneficial for preserving lean muscle mass in older populations, even in those with sarcopenia [53, 93]. In addition, muscle protein synthesis and myofiber proliferation can be effectively activated through MSE [94], which further contribute to skeletal muscle hypertrophy and muscle mass gains even in elder population [42, 43]. Therefore, MSE is recommend to be employed for management of OA since elder individuals with OA has been considered having low muscle mass [10].

However, it remains unclear that whether MSE has any effect on muscle mass gain and morphological changes in older individuals with lower extremities of OA. Studies have reported that patients with OA exhibited increased changes in the muscle cross-sectional area or muscle thickness after MSE [95–97], whereas other authors have reported conflicting conclusions that MSE exerted no beneficial effects on fat-free mass or muscle remodeling [98–100]. In addition, both sarcopenia and OA are associated with decreased muscle protein synthesis and homeostasis [75, 76], and exercise-induced muscular hypertrophy contributes to the increase of muscle strength [101]. Moreover, most of previous systematic reviews investigating the treatment efficacy of MSE for individuals with OA have focused on muscular strength and physical outcomes rather than the muscle mass or volume measures [87–90]. Therefore, identifying the effects of MSE on increasing muscle mass and volume helps clinical practitioners to develop appropriate treatment strategies for older people with OA.

Liao et al. conducted a systemic review and meta-analysis study to investigate effects of MSE for elder people with lower extremity OA [77]. Main results of systemic review and meta-analyses showed MSE has effects on changes in muscle mass gain (SMD = 0.49, 95% CI: 0.28, 0.71; $P < 0.00001$), muscle thickness (SMD = 0.82, 95% CI: 0.20, 1.43; $P = 0.009$), and muscle cross-sectional area (SMD = 0.80, 95%

CI: 0.25, 1.35; $P = 0.004$) compared with nonexercise controls. Liao's study demonstrated that MSE exerts effects on lean mass gain as well as muscle morphological changes in older adults with knee or hip OA. In addition, the subgroup analysis results suggested that older men experienced greater MSE effects on muscle thickness than did women peers and those who received MSE after arthroplasty may achieve greater changes in muscle volume compared to those who received preoperative an MSE intervention or those who did not undergo arthroplasty. According to the results in Liao's meta-analysis, MSE may aid in offsetting muscle attenuation or prevent sarcopenia in older individuals with knee or hip OA, particularly in older men and in those undergoing knee or hip arthroplasty.

3.2 Protein supplement

Diet intervention such as dietary protein or protein supplementation (PS) has been incorporated to multidisciplinary managements for OA [102], since elder patients with OA have potential risks of age-related sarcopenia. In addition, alternative and complementary therapeutic approaches, such as the use of a wide array of nutritional and physical manipulations, are becoming popular for relieving symptoms of OA. Several previous studies had investigated clinical efficacy of protein supplementation (PS) for elder individuals with knee OA [103–106]. Colker et al. employed a 6-week milk PS for elder individuals with OA and the results showed that PS achieved significant improved changes of daily activity and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) per week compared with the placebo group ($P < 0.001$) [104]; Zenk et al. conducted a similar study for older adults with OA and demonstrated that compared with the placebo supplement, a 6-week milk PS obtained significant effects on WOMAC and reduction of medication use as well as the glucosamine-supplement group did [106]. Arjmandi et al. further indicated that a 3-month soy-protein supplement achieved greater changes in pain, physical difficulty, and medical requirement than milk PS did, particularly for elder men with OA [103]. Regarding other types of PS, Miller et al. used an alternative PS of leucine enriched herbal and indicated that WOMAC and pain score were significantly reduced in PS group by 45% ($P < 0.05$) and 21.8% ($P < 0.002$), respectively, compared to the placebo group (reduced 25.4% in WOMAC and 21.8% in pain) [105].

3.3 Protein supplement combined with exercise training

Nutritional intervention, especially the protein supplementation (PS), can influence outcomes for elder individuals undergoing exercise interventions such as resistance-based exercise training (RET) or multicomponent exercise training (MET). Several systematic review studies had identified benefits of PS plus exercise training for elder population. For healthy elder individuals, Morton et al. reported that prolonged PS plus RET has effects on fat free mass, mid-thigh cross-sectional area, and one-repetition maximum strength by significant pooled mean differences of 0.30 kg (95%CI: 0.09–0.52 kg; $P = 0.007$), 7.2 mm² (95%CI: 0.20–14.30 mm²; $P = 0.04$), and 2.49 kg (95%CI: 0.64–4.33 kg; $P = 0.01$), respectively [67]. For overweight or obese elder individuals, Liao et al. indicated that PS plus RET exerts significant effects on LBM and muscle volume with the corresponding effect sizes being 0.58 (95% CI: 0.32–0.84; $P < 0.0001$) and 1.23 (95% CI: 0.50–1.96; $P = 0.001$), respectively, irrespective of the intervention period [61]. For frail elderly, Liao et al. demonstrated that PS plus either RET or MET exerts significant effects on LBM and leg strength with the corresponding effect sizes being 0.52 (95% CI: 0.33–0.71; $P < 0.00001$) and 0.37 (95% CI: 0.23–0.51; $P < 0.00001$),

respectively [68]. According to the previous established evidence regarding efficacy of PS plus exercise training, additional PS employed during exercise training may exert benefits for elder population with OA. However, most of the previous systematic review and meta-analysis studies investigated effects of PS plus exercise training for sarcopenic or frail elderly people, few studies focusing on OA population who are potentially with a high risk of sarcopenia. Further studies are necessary to investigate treatment effects of PS plus exercise on elderly population with OA.

3.4 Weight loss plus exercise for sarcopenic obesity in osteoarthritis

Given that obesity has become a burden in OA population [25], weight loss (WL) should be considered as an option while setting the treatment goals and planning rehabilitation strategies for elder people with OA. Previous studies had shown that maintaining or lowering BMI to the normal range (usually within 20.0–24.9, regardless of ethnic) may reduce risks or improve symptoms of OA [107, 108]. Felson et al. indicated that a decrease of over 50% in odds of developing OA (odds ratio = 0.46; $P = 0.02$) occurred in older women along with a 2-unit decrease in BMI or a 5.1-kg reduction in weight over a 10-year period, especially for those who had a baseline BMI > 25 kg/m² (odds ratio = 0.41; $P = 0.02$) [108]. Coggon et al. concluded similar results that proportion of knee OA patients can be reduced from 10.9 to 57.1% while overweight and obese populations reduced their weight by 2–5 kg or until reaching the normal-range BMI [107]. Weight loss is also efficacious in relieving symptoms of knee OA, most importantly alleviating the pain. Riddle et al. observed a significant dose-response relationship ($P < 0.003$) exists between percentage changes in body weight and the corresponding changes in WOMAC pain, as well as WOMAC physical function; Riddle further indicated that weight changes (gain or loss) of $\geq 10\%$ potentially leads to clinical important changes in pain and function for older individuals with OA [109]. Messier et al. also identified a dose response to WL for pain ($P = 0.01$), 6-minute walk distance ($P < 0.0001$), and function ($P = 0.0006$) [110]. Accordingly, WL should be incorporated to the management for elder individuals with OA, especially those who are overweight or obese.

An WL intervention may exert negative impacts on lean mass since obesity often masks the age-associated loss of muscle mass. Recently, WL in combination with exercise has been recommended as the optimal approach to managing obese patients with OA. Several previous trials had targeted weight management for obese older adults with OA including the Intensive Diet and Exercise for Arthritis Trial [111], the Arthritis, Diet and Activity Promotion Trial [112], and the Physical Activity, Inflammation, and Body Composition Trial [113]. These registered clinical trials employed weight-loss protocols which targeted 5–10% reduction of body weight over 6–18 months and incorporated partial meal replacements, nutrition class, and behavior therapy for diet habit changes and lifestyle modifications. Results from such previous trials showed that exercise training in combination with a weight-loss program in obese adults with knee OA achieved significantly greater changes in pain and function compared to the control groups. In addition, several systemic reviews regarding WL with or without exercise for elder OA populations also provide evidences for treatment efficacy on pain relief and function recovery [114–117]. However, the effects of WL plus exercise on lean mass remain inconsistency among the results of previous trials and few systemic review and meta-analysis studies focused on the treatment efficacy on muscle mass outcome in obese elder individuals with OA who received WL plus exercise. Future studies should be warranted to investigate effects of WL plus exercise on muscle mass in order to prevent sarcopenia in such elder population with OA.

Liao et al. conducted a systemic review and meta-analysis study to investigate effects of diet intervention plus ET for elder people with mild to moderate OA [118]. Among the included trials in Liao's study, all of the included trials which reported muscle mass outcomes conducted a WL plus ET intervention for obese elder patients with knee OA [118] and the results showed that during an overall follow-up duration, the WL plus ET group achieved significant effects on muscle mass gains (SMD = 0.61; 95%CI: 0.30–0.91, $P = 0.0001$) compared to the control groups, regardless of methodological design. The results indicated that WL plus ET exhibited significant effects on muscle mass for obese older individuals with OA.

4. Management of muscle dysfunction after total joint replacement for patients with end-stage osteoarthritis

4.1 Postoperative rehabilitation for muscle recovery after total joint replacement

Total joint replacement has been recommended for patients with end-stage of OA who experience poor response to pharmacological medication or conventional therapy [119–121]. Total knee replacement (TKR) as well as total hip replacement (THR) has profound benefits for pain relief, which is the main determinant of functional recovery following surgery.

Enhanced recovery programs after a TKR or THR surgery, which require a multidisciplinary team of dedicated professionals, have been well-established [122]. Among the perioperative interventions producing better surgery outcome, rehabilitation plays an important role in physical reconditioning and functional recovery [123]. As mentioned in the Section 2.1, muscle strengthening exercise (MSE) exerts benefits on muscle mass and strength gains in elder people with OA, and an MSE has been effectively employed following TKR or THR surgery as well to improve postoperative muscle and joint function [124]. However, it remains unclear that whether MSE exerts any effect on muscle mass after total joint replacement. It is important to identify the effects of MSE on muscle mass outcome following total joint replacement since patient who were undergoing TKR or THR may experience acute sarcopenia immediately after surgery [125, 126]. Due to that sarcopenia may have impacts on function outcome after TKR or THR, further studies should be conducted to warrant effective interventions for preserve muscle mass for elderly population with OA who recently underwent total joint replacement.

Liao et al. conducted a randomized control trial to investigate effects of post-TKR MSE for elder women with OA [127]. Liao's study demonstrated that an intervention of 12-week elastic RET following TKR surgery exerted benefits for muscle mass gain and physical recovery among elderly women with KOA. The results of this study suggest that elastic RET should be incorporated to post-TKR rehabilitation for patients with KOA to achieve well postoperative outcomes, especially muscle mass gains and physical mobility improvements. Liao further stated that the elastic RET is relatively safe and easily performed at home. The elastic RET protocol used in Liao's study will help clinical practitioners and physiotherapists and to establish prompt treatment strategies for elderly people with KOA, especially those who have undergone a recent TKR and are considered to have high sarcopenia risk. The findings of this study indicated post-TKR elastic RET exerted benefits on muscle mass and function and can potentially assist clinician decision-making concerning the optimal treatment strategy for elderly women who are undergoing a primary TKR.

4.2 Protein supplement plus exercise training after surgery

The previous observational study has indicated that low protein intake occurring in patients with OA may place themselves at high risks of sarcopenia [128]. Therefore, perioperative interventions including protein supplement may prevent elder patients from suffering acute sarcopenia and poor surgical outcome at early stage after total joint replacement (i.e., TKR or THR) [129–131]. Alito et al. employed 5-day protein-contained (23%) supplements (PS) before surgery for patients who were undergoing THR and the results demonstrated that comparing with the non-supplement control group, the PS group experienced significantly a lower level of C-reactive protein (mean 80.6 vs. 66.5 mg/L, $P < 0.01$) and a shorter length of hospital stay (median 6 vs. 3 days, $P < 0.01$) after THR [129]. Yang et al. used high-dose PS on the day before and after THR surgery and the results showed that, comparing to the standard-care group, the PS group had less proportion of patients who required an intravenous albumin (45.1% vs. 26.8%, $P = 0.023$) and experienced a shorter length of hospital stay (mean 5.1 vs. 3.9 days, $P < 0.001$) [130]. Bai et al. used an oral ingestion of hydrolyzed PS for 5 postoperative days after TKR and the results indicated that PS enhanced postoperative nutrition status in terms of greater changes in blood prealbumin ($P < 0.03$) compared to the regular-nutrition group [131]. The previous results had indicated that diet interventions, especially the PS, before or after total joint replacement can enhance postoperative nutrient status and shorten length of acute inpatient stay which further prevent elder patients from experiencing acute sarcopenia.

On the basis that either perioperative diet interventions or early rehabilitation programs exerts benefits on surgical outcome, combination of both may provide additional effects on function recovery after TKR or THR. The evidences regarding effects of PS plus exercise for healthy, sarcopenic, and frail elder populations have been well established by previous systemic review and meta-analysis studies [61, 68, 132]. However, the elder population with OA as well as those who underwent total joint replacement are less targeted by previous systemic reviews investigating efficacy of PS plus exercise. Future studies are necessary to be warranted in order to identify whether PS plus exercise following TKR or THR exerts any effect on postoperative function outcomes.

Liao et al. conducted a systemic review and meta-analysis study to investigate effects of diet intervention plus ET for elder people with OA [118]. Among the included trials in Liao's study, all of the included trials which reported muscle mass outcomes conducted a PS plus ET intervention for older patients who recently received a TKR or THR [118] and the results showed that during an overall follow-up duration, the PS plus ET group achieved significant effects on muscle mass gains (SMD = 0.81; 95%CI: 0.45–1.17, $P < 0.0001$) compared to the ET control groups, regardless of PS type. The results indicated that PS plus ET exhibited significant effects on muscle mass for older individuals with OA, especially for those who recently received a total joint arthroplasty.

5. Conclusions

This review provides evidence that DI incorporated with ET is effective for promoting gains in muscle mass and strength and enhancing performance in physical mobility for the elder adults with lower-extremity OA, compared to placebo, DI-alone or ET-alone controls. In addition, muscle mass gains have effects on strength gain and global function recovery. Furthermore, the results of this study showed that PS plus ET appears to be the optimal treatment strategy for

those who were undergoing total joint replacement whereas WL plus ET is most preferred for those who experienced mild to moderate severity of OA disease. Therefore, we concluded that DI additional to ET may have extra effects to prevent or offset muscle loss and function decline for elder individuals with OA who have high sarcopenia risks.

6. Implications for clinical practice

This review adds current evidences of interdisciplinary approach practices which comprise effective nutrient and exercise intervention strategies for KOA populations who have potential risks of sarcopenic obesity. This review also provides references for clinical practitioners to develop efficient and effective interventions for such population to prevent sarcopenic obesity.

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Conflict of interest

The authors declare that they have no conflict of interest to the publication of this review.

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